MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2016/2017

EME4016 – HEAT TRANSFER

(ME)

1 JUNE 2017
9.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question Paper consists of five pages including the cover page.
2. Answer ALL questions. Each question carries 25 Marks and the distribution of the Marks for each question is given in brackets [ ].
3. Write all your answers in the Answer Booklet provided.

Question 1

A large metal plate of thickness $l = 3$ cm is exposed to air for which $T_\infty = 25$ °C and $h = 20$ W/m^2·K. Uniform heat generation occurs within the plate at a volumetric rate $\dot{q} = 1 \times 10^5$ W/m^3. At time $t = 0$, the metal plate is at a uniform temperature, $T_i = 120$ °C. Assume negligible conduction resistance within the plate.
The properties of the plate are given as: $k = 25$ W/m·K and $\alpha = 12 \times 10^{-6}$ m^2/s .

(a) Determine the metal plate temperature at steady state. **[5 marks]**

(b) Calculate the Biot number of this problem. Hence, comment on the appropriateness of the assumption made in this question. **[5 marks]**

(c) State the energy balance equation for the metal plate under transient condition. **[3 marks]**

(d) Show from part (c) , the temperature of the plate, T as a function of time, t is :

$$T = \frac{\dot{q}l - [\dot{q}l - 2h(T_i - T_\infty)]\exp\left[-\left(\frac{2h}{\rho c l}\right)t\right]}{2h} + T_\infty$$ **[7 marks]**

(e) Find the temperature of the plate at time, $t = 3$ min. **[5 marks]**

Continued...

Question 2

A cylindrical close furnace has a length of $l = 1$ m and radius of $r = 0.25$ m. Both end surfaces of the furnace having emissivities, $\varepsilon_1 = \varepsilon_2 = 0.5$ are kept at temperature 300 K while the side surface having an emissivity, $\varepsilon_3 = 0.8$ is maintained at temperature 800 K. Subscripts 1, 2 and 3 denote end surface 1, end surface 2 and the side surface respectively.

(a) Determine view factors F_{12} and F_{31} respectively. **[6 marks]**

(b) Draw the circuit network to represent this problem. **[3 marks]**

(c) *Write down* the radiation heat transfer equations for this problem and *explain* clearly how to solve the net rate of radiation heat transfer from the side surface. Do not solve the equations and you may leave the equations in symbols. **[8 marks]**

(d) If the cylindrical furnace is open at both ends and the surrounding temperature is at 300 K, find the rate of radiation heat transfer from the side surface. **[8 marks]**

Take Stefan-Boltzmann constant to be 5.67×10^{-8} W/m^2·K^4.

Note: View factor between parallel, co-axial disks is given as

$$F_{12} = \frac{X - (X^2 - 4)^{1/2}}{2}$$

where $X = \frac{2R^2 + 1}{R^2}, R = \frac{r}{l}$

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Question 3

Blood is cooled from 40 °C to 25 °C as it flows through a coiled tube of 5-mm diameter at 0.2 m/s. The coiled tube is placed in a vat of *water-ice mixture*. Blood properties may be approximated as: $\rho = 1000\,\text{kg/m}^3$, $k = 0.5\,\text{W/m}\cdot\text{K}$, $\nu = 7 \times 10^{-7}\,\text{m}^2/\text{s}$ and $c_p = 4.0\,\text{kJ/kg}\cdot\text{K}$. Neglect all entrance effects and assume *fully developed* conditions.

(a) Determine the rate of heat loss from the blood as it flows through the tube. **[5 marks]**

(b) What is the Reynolds number of the blood flow ? **[3 marks]**

(c) Determine the average heat transfer coefficient for the blood flow in the tube. **[6 marks]**

(d) Approximate the length of the tube required for this cooling. **[6 marks]**

(e) Sketch and reason on the surface heat flux variation along the axial direction of the tube. **[5 marks]**

Note:

Convection correlations for flow in a circular tube are:

Correlation		Conditions
$Nu_D = 4.36$	(8.53)	Laminar, fully developed, uniform q_s''
$Nu_D = 3.66$	(8.55)	Laminar, fully developed, uniform T_s
$\overline{Nu}_D = 3.66 + \dfrac{0.0668(D/L)Re_D Pr}{1 + 0.04[(D/L)Re_D Pr]^{2/3}}$	(8.56)	Laminar, thermal entry (or combined entry with $Pr \gtrsim 5$), uniform T_s
or		
$\overline{Nu}_D = 1.86\left(\dfrac{Re_D Pr}{L/D}\right)^{1/3}\left(\dfrac{\mu}{\mu_s}\right)^{0.14}$	(8.57)	Laminar, combined entry, $0.6 \lesssim Pr \lesssim 5$, $0.0044 \lesssim (\mu/\mu_s) \lesssim 9.75$, uniform T_s
$Nu_D = 0.023 Re_D^{4/5} Pr^n$	(8.60)[c]	Turbulent, fully developed, $0.6 \lesssim Pr \lesssim 160$, $Re_D \gtrsim 10{,}000$, $(L/D) \gtrsim 10$, $n = 0.4$ for $T_s > T_m$ and $n = 0.3$ for $T_s < T_m$
or		
$Nu_D = 0.027 Re_D^{4/5} Pr^{1/3}\left(\dfrac{\mu}{\mu_s}\right)^{0.14}$	(8.61)[c]	Turbulent, fully developed, $0.7 \lesssim Pr \lesssim 16{,}700$, $Re_D \gtrsim 10{,}000$, $L/D \gtrsim 10$
or		
$Nu_D = \dfrac{(f/8)(Re_D - 1000)Pr}{1 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)}$	(8.62)[c]	Turbulent, fully developed, $0.5 \lesssim Pr \lesssim 2000$, $3000 \lesssim Re_D \lesssim 5 \times 10^6$, $(L/D) \gtrsim 10$

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Question 4

Glycerin at 20 °C and 0.2 kg/s is to be heated by ethylene glycol at 56 °C in a thin-walled double-pipe *counter-flow* heat exchanger. Glycerin leaves the heat exchanger at 45 °C. Ethylene glycol has a mass flow rate higher than glycerin. The overall heat transfer coefficient is 450 W/m^2·°C and the heat transfer area is 1.6 m^2.

(a) Find the rate of heat transfer. **[4 marks]**

(b) Determine whether the hot or cold fluid has a lower thermal capacity. **[3 marks]**

(c) What is the effectiveness of the heat exchanger ? **[5 marks]**

(d) Use NTU method to estimate:

(i) the mass flow rate of ethylene glycol and **[7 marks]**

(ii) the outlet temperature of ethylene glycol. **[6 marks]**

The specific heat capacity for glycerin is c_p =2400 J/kg·°C and the corresponding value for ethylene glycol is c_p =2500 J/kg·°C.

Note : You may need to refer to Figure Q4.

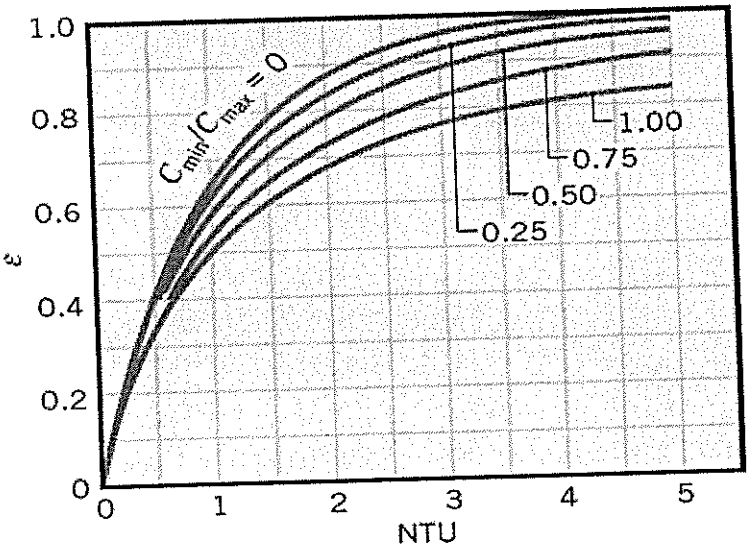

Figure Q4: Effectiveness of a counterflow heat exchanger

End of paper.